Age and growth of *Diplodus vulgaris* (Sparidae) in the Gulf of Tunis

by

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ABSTRACT. - Age and growth of the two-banded seabream (*Diplodus vulgaris*) from the Gulf of Tunis were investigated using scales and otoliths. Total length (TL) and weight (TW) ranged respectively from 10 to 32 cm and from 14 to 525 g (n = 570). The length-weight relationship was slightly but significantly allometric (b = 3.05 ± 0.02 s.e.) when data from both sexes were pooled. Marginal increment analysis proved that annuli were formed once a year, in June. Age readings were precise for the two hard structures, with low values of the index of average percent error. The power function well described the relationship between TL and scale or otolith radius (r > 0.92). The von Bertalanffy growth equation was fitted on mean backcalculated length-at-age data resulting in the following parameter values for scales ($L\infty$ = 39.9 cm, k = 0.11 year^{-1}, t_0 = -0.73 year) and for otoliths ($L\infty$ = 39.0 cm, k = 0.10 year^{-1}, t_0 = -0.96 year). Although scale readings provided a better fit, otolith readings could also be used with fairly good results. Among Sparids, *D. vulgaris* is a relatively slow growing and a moderate-lived species, with a maximum observed age of 12 years. Total length at maturity (TL 50) was 17.6 cm for males and 17.1 cm for females, which corresponds to an age of about 4 years. Large discrepancies in growth parameters between geographic areas are the result of different growth patterns.

RÉSUMÉ. - Âge et croissance de *Diplodus vulgaris* (Sparidae) du golfe de Tunis.

L'âge et la croissance du sar à tête noire (*Diplodus vulgaris*) ont été déterminés à partir de 570 spécimens collectés dans le golfe de Tunis, en utilisant les écailles et les otolithes. La longueur totale variait entre 10 et 32 cm et le poids total entre 14 et 525 g. La relation taille-poids est faiblement, mais significativement, allométrique pour les sexes regroupés avec une valeur b = 3,05 (e.s. = 0,02). Les analyses de l'accroissement marginal ont mis en évidence la formation d'un seul annulus par an au mois de juin. Les lectures d'âge se sont révélées très précises pour les deux structures dures, avec un faible pourcentage moyen d'erreur. La longueur totale du poisson et la mesure des rayons de l'écaille ou de l'otolithe sont étroitement corrélées. L'équation de croissance de von Bertalanffy, estimée à partir des couples âge-longueurs rétro-calculées, fournit les paramètres suivants pour les écailles ($L\infty$ = 39,9 cm, k = 0,11 an^{-1}, t_0 = -0,73 an) et pour les otolithes ($L\infty$ = 39,0 cm, k = 0,10 an^{-1}, t_0 = -0,96 an). Même si les données indiquent que les écailles semblent plus appropriées pour la lecture de l'âge, les otolithes peuvent être utilisés avec des résultats également satisfaisants. Parmi les sparidés, le sar à tête noire est une espèce à croissance relativement lente et à longévité modérément longue avec un âge maximal de 12 ans. La taille de maturité à 50% est de 17,6 cm pour les mâles et 17,1 cm pour les femelles, ce qui correspond à environ 4 ans. Les paramètres de croissance manifestent de grands écarts entre les régions et traduisent des modèles de croissance différents.

Keys words. - Sparidae - *Diplodus vulgaris* - MED - Gulf of Tunis - Age - Growth - Age at maturity.

The two-banded seabream *Diplodus vulgaris* (E. Geoffroy St.-Hilaire, 1817) is a demersal marine fish, which inhabits inshore waters on rocky or sandy bottoms and *Posidonia* beds down to 90 m depth. It is a common fish with a wide distribution range in the Eastern Atlantic, from the Bay of Biscay to the Cap Verde Islands and around the Madeira and the Canary Islands, and from Angola to South Africa. It is also present throughout the Mediterranean Sea and in the Black Sea (Bauchot and Hureau, 1986).

Sparid fishes account for 13% of total commercial catches from the Gulf of Tunis. The genus *Diplodus* includes highly valuable commercial species in Tunisia and constitutes 20% of the total catches of seabreams from the gulf of Tunis (Anonymous, 2006).

Despite the wide distribution range and commercial importance, most data on the biology of *D. vulgaris*, such as feeding, reproduction and growth, are limited to the eastern Atlantic, namely the Canary Islands (Pajuelo and Lorenzo, 2003; Pajuelo *et al*., 2006), the Portuguese coasts (Gonçalves and Erzini, 1998; Gonçalves and Erzini, 2000; Gonçalves *et al*., 2003; Abecasis *et al*., 2008), and to the north-western Mediterranean (Gordoa and Moli, 1997) and the Adriatic Sea (Pallaoro *et al*., 2006).

Only one study has examined the growth of *D. vulgaris* in the Gulf of Gabes (south Tunisian coasts) (Bradai *et al*., 1998). Yet, little is known on the biology of that exploited species along the Tunisian coasts, and basic and biological information are required for its sustainable management.

This paper aims to extend the current knowledge on basic aspects, such as age and growth, to the Gulf of Tunis (north Tunisian coasts). First, the reliability of age estimates of *D. vulgaris* was tested by evaluating the precision of two

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hard structures, scales and otoliths, and by validating the yearly frequency and timing of ring formation in both hard pieces. The purpose was to select the more suitable and accurate hard structure, on which to base age assessment for that species. Secondly, age and growth of fish were estimated from the analysis of marks recorded in the two hard structures and compared with those reported from other areas.

MATERIAL AND METHODS

Studied area, fish sampling and collection of hard structures

A sample of 570 specimens of *D. vulgaris* was obtained from the landings of the small-scale artisanal fisheries of the Gulf of Tunis. The specimens were randomly collected fortnightly from October 2005 to September 2006. Fish were measured to the nearest mm for total length (TL) and weighed to the nearest gram for total weight (TW). Individuals were sexed as males, females, immatures and hermaphrodites after a macroscopic observation of the gonads. Sagittal otoliths were removed from each specimen, cleaned and stored dry. Scales were sampled from the left side of the body beneath the pectoral fin, cleaned and mounted between glass slides.

Scale and otolith analysis

Scales were read under reflected light using a compound microscope and magnifications between 10x and 40x. Annuli were generally clearly identifiable; one annulus appears as a clear and thick hyaline line with a contour parallel to the edge of the scale. The radii of the scale (Rs) and of the annual increments were measured along a line passing through the focus and roughly bisecting the anterior field of the scale.

The age was read from the whole otoliths immersed in a blackened bottom watch glass containing glycerine (25%) and alcohol (75%) in order to increase the contrast between rings. Following Abecasis *et al.* (2008), otoliths were viewed with a low-power binocular microscope under reflected light. The opaque zones appeared as bright rings and the translucent zones as dark rings. The association of one opaque zone and one subsequent translucent zone was considered to compose a yearly annulus as in most fish species. The count path of annuli was from the core towards the tip of the rostrum where they were the most visible. Distance from otolith core to rostrum (Ro) and radius of each annulus were measured with an ocular micrometer.

To assess ageing precision, readings were undertaken twice for each structure without any ancillary data on fishes; interpretations were done with an interval of a few months to avoid subjectivity effect on age estimations. To minimize errors only coincident readings were accepted. The index of average percentage error (IAPE), which measures the amount of variation between age readings for otoliths and scales (Beamish and Fournier, 1981), was then calculated using the formula:

$$\text{IAPE} : 1 / N \sum_{j=1}^{N} [1 / R \sum_{j=1}^{R} (Xij - Xj / Xj)] \times 100$$

where N is the number of fish aged, R is the number of readings, Xij is the *ith* age determination of the *jth* fish and Xj is the mean age calculated for the *jth* fish.

Data analysis

The length-weight relationship of fish was estimated by the power function $TW = a\, TL^b$, where TW is the total weight (g) and TL the total length (cm). The regression parameters a and b, and the coefficient of determination (r^2) were estimated, both for the whole population and for each sex, by least square linear regressions after log transformation of both variables. According to Ricker (1973), the slope of the regression was corrected to follow a geometric mean regression. An ANCOVA test was used to compare regression lines between sexes and a t-test to appreciate the hypothesis of isometric relationship (H0: slope = 3; H1: slope ≠ 3) (Zar, 1999).

To validate the seasonality and the timing of ring formation in the scales and otoliths, the monthly mean marginal increment was analysed (Jearld, 1983). The marginal increment (MI, 0.01 mm) was measured as the distance from the inner margin of the outermost ring and the periphery of each otolith or scale. The Kruskal-Wallis test was used to test the homogeneity of MI among months followed by a Student-Newman-Keuls nonparametric (SNK) test after null hypothesis rejection (Zar, 1999). The minimum marginal increment was used to indicate the month of annulus formation.

Once the periodicity of rings was confirmed to be annual, the age of each fish was attributed knowing the number of annuli, the assumed birth date and the sampling date. A study of the reproductive biology of *D. vulgaris* in the Gulf of Tunis indicates that the peak of the reproductive season is between December and January (Mouine *et al.*, 2006); thus, 1st January was chosen as the birth date.

To increase the number of observations in length-at-age data, backcalculation was performed using the body proportional hypothesis method applied to a power function between fish length and calcified structures radius (Francis, 1990; Horpila and Nyberg, 1999). The relationship between the radius of the scale or the otolith at capture and the TL was estimated by regressions of log (TL) on log (Rs) or log (Ro). The length of an individual when the *ith* band is laid down (Li, mm) was calculated according to the formula: $Li = (Ri/R) - Lc$, where Ri is the radius of the *ith* band, R is the radius of otolith or scale at capture, Lc is the length at capture and ν is the constant derived from the power function that describes the relationship between the radius of the cal-

cified structures and total length of fish (Francis, 1990). To summarize the age composition of *D. vulgaris*, age-length keys were constructed.

The von Bertalanffy growth model, by far the most commonly used to estimate growth in fishes, was fitted to the backcalculated mean length at age for the whole population by means of Marquardt's algorithm for nonlinear least squares parameter estimation (Saila *et al.*, 1988). Statistical comparisons of growth equations between structures (otoliths and scales) were conducted using Hotteling tests (Zar, 1999).

The growth performance index Φ' (Φ'= 2 log L∞ + log k) was employed to compare growth rates of *D. vulgaris* from different fishing areas (Munro and Pauly, 1983).

The length at first maturity (TL50) is the length at which 50% of the fish are mature. It was expressed as the proportion of mature fish in each size-class and determined from the following logistic function (Saila *et al.*, 1988):

$P = 1 / (1 + e^{-b\,(TL - TL50)})$, with P: proportion of mature fish for the length TL; b: slope of the maturity curve and TL50: size at which 50 % of the fish are mature.

The function was fitted to the data using the Marquardt algorithm for non linear least squares regression. Multivariate analysis (Hotelling's T^2 test) was used to compare the logistic model parameter estimates for males and females (Bernard, 1981).

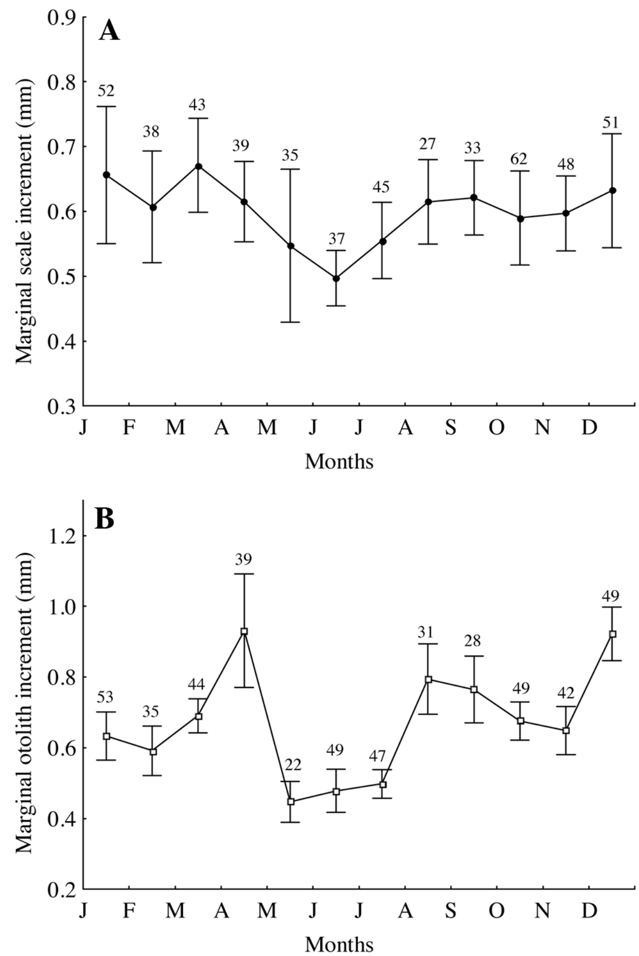


Figure 1. - Mean monthly marginal increments of scales (**A**) and otoliths (**B**) for *Diplodus vulgaris* of the Gulf of Tunis. Error bars = ± standard error with number of individuals above.

RESULTS

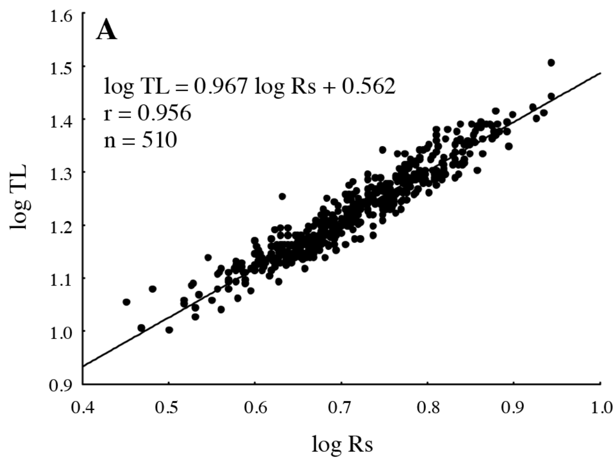
Fish size and length-weight relationship

Of the fish examined, 108 were males, 297 females and 11 hermaphrodites. The sex of the remaining 154 fish could not be determined macroscopically. They were considered as immatures. The sex ratio differed significantly from 1:1 (χ^2; n = 405, $p < 0.05$). Females ranged in size from 12.3 to 32.0 cm TL and males from 11.9 to 27.8 cm TL. The mean TL of females (TL = 18.2 ± 0.2 cm) was not significantly different (Mann-Whitney U test; n = 405; p = 0.93) from that of males (TL = 18.1 ± 0.3 cm). Hermaphrodites were found at TL between 10.0 and 17.3 cm and immatures between 13.8 and 21.1 cm. The total weight of fish was between 30 and 525 g (TW = 103.6 ± 3.8 cm) for females and between 27 and 378 g (TW = 100.5 ± 5.2 cm) for males (Mann-Whitney U test; n = 405; p = 0.88).

Length-weight regression parameters estimated for males, females and the whole sample are presented in table I. The length-weight relationships were found significant ($p < 0.001$) in the three groups. Males exhibited isometric relationship (t-test, n = 108, p = 0.130) and females positive allometric relationship (t-test, n = 297, p = 0.027). When all individuals were pooled together, positive allometry was observed in length-weight relationship (t-test, n = 570, p = 0.014). However, allometry was very small with coefficients close to 3 and there were no statistically significant differences in slopes or intercepts between males and females (ANCOVA, n = 405, p > 0.05).

Table I. - Parameters of weight-length relationships for females, males and all fish (males, females, immatures and hermaphrodites) of *Diplodus vulgaris* in the Gulf of Tunis. All the three relationships were significant (ANOVA, $p < 0.001$). The isometry was tested by Student's t-test (H_0: b = 3). a: intercept; b: slope; s.e. (b): standard error of b; n: sample size; r^2: coefficient of determination.

	a	b	s.e (b)	n	r^2	t-test	p
Males	0.013	3.058	0.038	108	0.969	1.524	0.130
Females	0.012	3.078	0.035	297	0.960	2.228	0.027
All fish	0.013	3.054	0.022	570	0.971	2.455	0.014



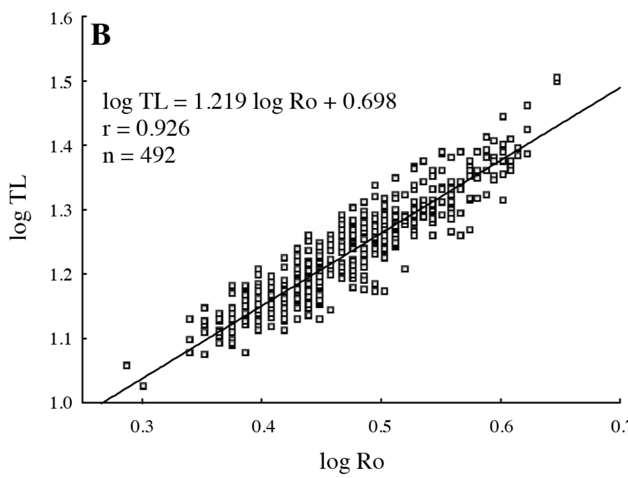


Figure 2. - Relationships between scale (**A**) or otolith (**B**) radius and total length (TL) in cm for *Diplodus vulgaris* of the Gulf of Tunis.

Age accuracy and precision

Among the total scales examined, 510 (89.5%) yielded useful age estimates and 60 were discarded because they were considered as unreadable (n = 28) or presented a discrepancy of readings (n = 32). Of the total otoliths removed, 492 (86.3%) were easily used for age estimation, 32 were broken or difficult to interpret, 34 provided different age estimations across successive readings and were then excluded from the analysis. The index of average percent error (IAPE) value was low, 3.5% for scales and 4.2% for otoliths, indicating for each structure a good reproducibility between readings. The IAPE exceeded 10% if all readings were taken into account.

Validation of otolith and scale increment

The lowest monthly mean marginal increments were recorded from May to July for scales (Kruskall-Wallis test, p = 0.46) and for otoliths (Kruskall-Wallis test, p = 0.00)

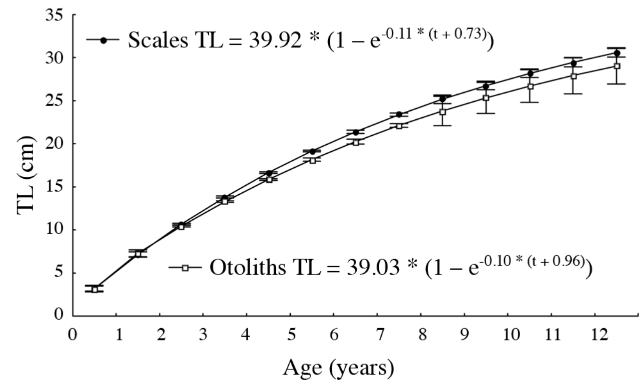


Figure 3. - Age-length relationships from scales and otoliths and growth parameters estimated by a non linear regression from scales and otoliths for *Diplodus vulgaris* of the Gulf of Tunis. Error bars = ± standard error.

with an increasing trend throughout the year (Fig. 1). Thus, the marginal increment analysis performed on the entire fish sample validates the annual deposition of one single annulus, which is laid down at the beginning of the summer.

Hard structure size and fish size relationships

Fish total length and radii of the calcified structures were closely correlated (Fig. 2). A power relationship was estimated between the total length and the scales radius and between the total length and the otoliths radius. The value of the slope b was significantly different from 1 (t-test, $p < 0.05$) for the two structures; thus, a negative allometric relationship was recorded for scales and a positive allometric one for otoliths.

Age and growth

To summarize the age composition of *D. vulgaris*, age-length keys were constructed (Tab. II). Age estimates ranged between 1 and 12 years for scalimetry and between 1 and 11 years for otolithometry. However, the sample was mostly composed of 3-4 year-old fish, which represented 58.0% of individuals treated by scalimetry and 56.3% of those treated by otolithometry.

Individuals grew faster during the first year of life, attaining approximately 25% of their maximum length. Annual growth rate stabilized towards 9 or 10 years (Fig. 3).

A von Bertalanffy growth function (VBGF) was fitted to age and backcalculated length data for the whole population (Fig. 3). The estimated growth parameters for scales and otoliths were not significantly different (Hotteling T^2 test, $T^2 = 1.53$; $p > 0.05$). The variance explained by the non-linear regression lines (r^2) was similar as well when fitted to otoliths (0.99) than to scales readings (0.98). However, the standard deviations of parameters were smaller for the estimation based on scales readings (scales: $L\infty = 39.9 \pm 2.76$ cm; $k = 0.11 \pm 0.01$ year^{-1}; $t_0 = -0.73 \pm 0.26$ year. Otoliths: $L\infty = 39.0 \pm 5.92$ cm; $k = 0.10 \pm 0.03$ year^{-1}; $t_0 = -0.96 \pm 0.50$ year).

Table II. - Age-length key for all fish of *Diplodus vulgaris* of the Gulf of Tunis aged using scales and otoliths (between parentheses). m: means (in cm); s.e: standard error; n: sample size.

Size	Age groups (years)											
(cm)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
7	1 (-)											
8												
9	4 (1)											
10	5 (3)	3 (3)										
11	4 (-)	17(25)	1 (1)									
12		19(25)	7 (6)									
13		14(11)	63(46)	1 (-)								
14		3 (3)	56(70)	3 (4)								
15			33(45)	20 (11)								
16			12(9)	28 (25)	3 (7)	- (2)						
17			3 (1)	39 (29)	4 (16)	- (6)						
18			1 (-)	19 (18)	25(19)	1 (8)						
19				7 (7)	31(12)	- (6)						
20				3 (3)	15 (5)	5 (10)						
21				- (2)	9 (4)	7 (13)	- (3)					
22					2 (-)	7 (9)	3 (6)					
23						6 (1)	5 (6)					
24					1 (-)	5 (1)	7 (2)	- (1)				
25						2 (-)	1 (-)	- (1)	- (1)		- (1)	
26								2 (-)				
27								1 (1)	1 (-)			
28									- (1)	1 (2)	- (1)	
29												
30								- (1)			1 (-)	
31								- (1)	- (1)	- (1)		1 (-)
32											- (1)	
m	9.8	11.8	13.9	16.6	19.0	21.9	23.6	26.2	27.1	27.9	30.0	30.7
s.e	0.3	0.1	0.1	0.1	0.1	0.2	0.2	0.5	-	-	-	-
n	14	56	176	120	90	33	16	3	1	1	1	1
(m)	(9.6)	(11.7)	(14.0)	(16.8)	(18.0)	(19.7)	(22.3)	(27.9)	(28.0)	(28.2)	(28.3)	
(s.e)	(0.4)	(0.1)	(0.1)	(0.1)	0.2	(0.3)	(0.2)	(1.7)	(1.8)	(1.9)	(2.1)	
(n)	(4)	(67)	(178)	(99)	63	(56)	(17)	(5)	(3)	(3)	(3)	

The growth in weight described by a von Bertalanffy function was respectively for scales and otoliths:

$$TW = 1009.2 * (1 - e^{-0.114 * (t + 0.728)})^{3.054}$$

$$TW = 942.0 * (1 - e^{-0.105 * (t + 0.962)})^{3.054}$$

The annual growth rate in weight was slightly higher when estimated from scales than from otoliths, the difference being notably more pronounced with age rising. The growth rate in weight was minimal during the first year (5%), whereas it increased with age (12% for the second year and 43% for 6 years), and stabilized at about 9 years (49%).

Length and age at first maturity

Length at first maturity was significantly similar (Hotelling T^2 test, $p = 0.46$) for males (17.6 ± 0.2 cm TL) and females (17.1 ± 0.3 cm TL). TL50 was 17.4 ± 0.2 cm ($n = 144$) for the pooled sex. Age at maturity for both sexes

combined was 4.3 years and 4.6 years when estimated from the growth curves established respectively from scales and from otoliths.

DISCUSSION

One of the main problems in ageing is the selection of the most suitable and accurate structure. Age estimation by means of scales is widely used because these hard structures are collected, prepared and read easily. Scalimetry has often been found to be capable of providing satisfactory results but has also been criticized for the frequent underestimation of the age of old fish (Beamish and McFarlane, 1983; Carlander, 1987). Alternatively, otolith characteristics make them appropriate for age estimation. They do not act as calcium stores and cannot be lost during the life of an individual, thus always providing a complete sequence of growth structures (Morales-Nin and Panfili, 2002).

Growth increments were clearly identified and interpreted when reading scales of *D. vulgaris*. The use of sagittal otoliths for age determination proved straightforward because they exhibited seasonal increments with different opacities surrounding a white opaque core. Owing to translucency, observation of the whole otolith provided an easy age reading, without having to prepare thin sections. Otoliths of *D. vulgaris* show the common ring pattern of temperate teleost fishes with one opaque mark and one translucent mark formed each year corresponding to rapid and to slow growth, respectively. Seasonal growth cycles might be related to a complex control by environmental and endogenous factors (Beckman and Wilson, 1995). The physiological changes are produced mainly by the influence of temperature, food supply and reproductive cycle (Pannella, 1980).

Rabenevanana (1985) studied age of *D. vulgaris* by scalimetry in the Gulf of Lion and reported a renewal of growth after a decrease in winter, with the growth mark formation starting in June. Similar results were obtained in the present study by the marginal increment analysis, which validated the pattern of an annual deposition of annuli for both scales and otoliths.

The high correlation found between TL and otoliths or scales indicates that both hard structures are useful for estimating age and for reconstructing past growth history of fishes by backcalculation (Campana, 1990; Francis, 1990). Results indicate that scales of large individuals grow at a much slower rate than the body, while otoliths have a positive allometric growth, as observed by Casselman (1990).

For *D. vulgaris*, the two hard structures give similar mean length at ages. The maximum age was 12 years and 11 years for scales and otoliths, respectively. As reported by Abecasis *et al.* (2008), our estimation of age by reading the whole otolith, could have underestimated the ages of greater fish due to the thickening of the whole otolith margin. The standard deviations of the growth parameters were lower for estimates based on scale readings than on otoliths although the scales readings in the present study presented a better fit. On the contrary, Abecasis *et al.* (2008) stated that otoliths were more appropriate for the age interpretation of *D. vulgaris* because they found smaller standard deviations of the means for estimates based on otolith readings than on scales. Moreover, for large individuals over 6 years old, a greater percentage of otoliths (4.4% for scales and 6.2% for otoliths) proved to be easier to read since scales presented a closeness of the growth increments. Nevertheless, in our opinion, both hard structures have a high success rate in reading and interpretation.

The estimated value of the theoretical maximum length obtained in this study is reasonable since it is higher than the size of the largest fish sampled. Gonçalves *et al.* (2003) found an asymptotic length smaller than the maximum length and stated that this may be due to the fast growth in the first few years of life, which considerably slows down afterwards. The growth coefficient value indicates a relatively slow attainment of maximal size, which is rather characteristic of a long life cycle species. According to Buxton (1993), slow growth and longevity are common for sparids, but *D. vulgaris* is relatively fast growing compared with other species of the same genus such as *D. sargus* and *D. cervinus* (Gonçalves *et al.*, 2003; Abecasis *et al.*, 2008).

The comparison of growth parameter estimates of *D. vulgaris* from different geographical areas shows substantial discrepancies (Tab. III). These differences can be attributed to differences in the environmental conditions of the different areas or to bias introduced by methodological approaches (ageing and statistical analyses procedures, length composition of the samples). *D. vulgaris* of the Gulf of Tunis has the lowest growth coefficient (k) but reaches a larger $L\infty$ value than in the other regions. Our estimates of $L\infty$ were similar for both hard structures because the samples were: 1) similar in size range and in number of individuals treated; and, 2) age readings were closely related in otoliths and scales. Our $L\infty$ values are rather in agreement with those reported by Rabenevanana (1985) and Pajuelo and Lorenzo (2003). These authors also used an indirect method and worked on an almost similar size range of fish. Gordoa and Moli (1997), Bradai *et al.* (1998), Gonçalves *et al.* (2003) and Abecasis *et al.* (2008) found underestimated asymptotic lengths, which are probably due to the absence or scarcity of large individuals in their samples and which may also be the reason why growth rates were consequently overestimated in some studies. Gonçalves *et al.* (2003) and Abecasis *et al.* (2008) also included individuals smaller than 7.5 cm in their computation and used the mean length-at age to fit the von Bertalanffy equation while we used a mean backcalculated length-at age relation such as in Pajuelo and Lorenzo (2003).

Table III. - Biogeographic comparison of von Bertalanffy growth function parameters and growth performance index (Φ') of *Diplodus vulgaris*. $L\infty$: asymptotic length; k: growth coefficient; t_0: theoretical age at zero length; n: sample size; Age max: maximum age.

Authors	Localities	Age determination	$L\infty$ (cm)	k ($year^{-1}$)	t_0 (year)	n	TL (cm)	Φ'	Age max
Rabenevanana (1985)	Gulf of Lion	Scales	37.8	0.183	-0.83	556	10.0 - 35.0	2.41	14
Gordoa and Moli (1997)	Catalan coast	Otoliths	28.8	0.389	-0.657	201	8.0 - 28.0	2.51	6
Bradai *et al.* (1998)	Gulf of Gabes	Scales	23.5	0.224	-1.446	97	10.8 - 32.0	2.09	8
Gonçalves *et al.* (2003)	South of Portugal	Otoliths	27.7	0.400	-0.340	1076	7.5 - 30.5	2.49	14
Pajuelo and Lorenzo (2003)	Canary Island	Otoliths	39.9	0.215	-0.928	624	12.8 - 36.5	2.53	9
Abecasis *et al.* (2008)	South of Portugal	Scales	34.5	0.180	-1.270	377	3.0 - 35.0	2.33	14
		Otoliths	27.4	0.400	-0.770	1076	3.0 - 37.0	2.48	14
Present study	Gulf of Tunis	Scales	39.9	0.114	-0.728	510	10.0 - 32.0	2.26	12
		Otoliths	39.0	0.105	-0.962	492	10.6 - 32.0	2.20	11

Thus, the significant differences found in growth rates and $L\infty$ values in the different studies may be partly due to differences in methodologies and in the size range of sampled fish. Alternatively, they may indicate the existence of different populations of the same species, with their own variation in growth rate as a result of different levels of fishing pressure that could consequently affect the size structure of stocks. However, the growth performance index values are very close among localities (Tab. III) and are therefore characteristic of the species (Chilari *et al.*, 2006).

The maximum age observed in the present study was 12 years for a fish of 32.0 cm TL. *D. vulgaris* of the Gulf of Tunis has a smaller longevity than on the south of Portugal and on the Gulf of Lion coasts but a longer life span than in the Gulf of Gabes, Catalan and Canary Islands waters (Tab. III).

The length-weight relationship parameters for *D. vulgaris* from different areas obtained by various authors are given in table IV. The b value varies between 2.431 and 3.133 showing different growth modes. The length-weight relationship is a practical index of the condition of fish. The pattern of weight relative growth may fluctuate over the year according to factors such as food availability, feeding rate, gonad development or spawning period (Bagenal and Tesch, 1978). The differences in b value observed for the species across areas may be attributed to the different trophic conditions (Chilari *et al.,* 2006). In fact, the Mediterranean Sea, and the Eastern Basin in particular, is considered as one of the most oligotrophic regions in the world in terms of both primary productivity and chlorophyll a concentrations (Azov, 1991).

The lengths at first sexual maturity estimated for the Gulf of Tunis are close to those estimated by Gonçalves *et al.* (2003) (17.3 cm TL for males and 17.7 cm TL for females) for the Portuguese coasts but are smaller than sizes recorded by Pajuelo *et al.* (2006) (19.5 cm TL for males and 20.9 cm LT for females) in the Canary Islands. In the Gulf of Tunis, age at maturity for pooled sex is about four years old, while it is two years in the Atlantic (Gonçalves and Erzini, 2000; Pajuelo *et al.*, 2006). Thus, slower growth and more delayed maturity of *D. vulgaris* are observed in the Gulf of Tunis than in the Atlantic. According to Duponchelle and Panfili (1998), variations in age at maturity are mainly explained by growth differences, while variation in size at maturity are explained either by growth difference for fishes of same age or by age differences induced by growth differences. Size and age at maturity may be dependent on environmental and genetic factors (Wooton, 1998), and also on long-term fishing pressure (Jennings *et al.*, 2001).

The current minimum legal size (11 cm) in Tunisia following the actual legislation is less than our estimated size at maturity (17.4 cm TL). If we assume that the length composition of our samples reflects that of the commercial fishery, then 58% of the fish captured are smaller than our estimated

Table IV. - Parameters of the length-weight relationship of *Diplodus vulgaris* by authors and study area. n: simple size; min and max: minimum and maximum total length (TL); a and b: parameters of the relationship; s.e (b): standard error of the slope b; r^2: coefficient of determination. *: the authors give total length in mm.

Authors	Regions	TL (cm)			Parameters of length-weight relationships				
		n	min	max	a	b	s.e (b)	r^2	p
Rabenevanana (1985)*	Gulf of Lion	577	10.0	35.0	8.05×10^{-6}	3.133	-		
Gançalves *et al.* (1996)*	Portugal	975	16.0	34.5	10.5×10^{-6}	3.083	-		
Can and Basusta (2002)	South of Turkey	105	13.2	27.0	0.013	3.124	0.082	0.933	> 0.05
Moutopoulos and Stergiou (2002)	Aegean Sea (Greece)	122	11.6	29.6	0.013	3.055	0.036	0.980	> 0.05
Morey *et al.* (2003)	West of Mediterranean	328	3.8	28.2	0.015	3.006	0.093	0.997	> 0.05
Karakulak *et al.* (2006)	Aegean Sea (Turkey)	93	9.0	25.0	0.086	2.431	0.188	0.647	< 0.05
Present study	Gulf of Tunis	570	10.0	32.0	0.013	3.054	0.022	0.971	< 0.05

length at 50% maturity. Therefore, an increase in the minimum authorized length should be beneficial for the conservation of *D. vulgaris*. The moderate longevity, relative slow growth and relatively late maturation of *D. vulgaris* are life history traits that make its stock prone to overexploitation.

Acknowledgements. - We are grateful to the two anonymous reviewers for the correction of the manuscript and for their helpful comments and suggestions. Thanks to the organizing committee of RIF 4 meeting for the financial support attributed to Nejla Mouine in order to attend the meeting in Paris.

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